

## LOAD LOCK CHAMBER WITH GAS-SEALING BELLOWS

### Field of the Invention

[001] The present invention relates to process chambers such as etching chambers used in the etching of material layers on a semiconductor wafer substrate to fabricate semiconductor integrated circuits on the substrate. More particularly, the present invention relates to a load-lock chamber provided with a gas-sealing bellows in a semiconductor substrate processing system to reduce or eliminate outgassing and leaking of gas from a lift shaft in the chamber.

### Background of the Invention

[002] In the semiconductor production industry, various processing steps are used to fabricate integrated circuits on a semiconductor wafer. These steps include the deposition of layers of different materials including metallization layers, passivation layers and insulation layers on the wafer substrate, as well as photoresist stripping and sidewall passivation polymer layer removal. In modern memory devices, for example, multiple layers of metal conductors are required for providing a multi-layer metal interconnection structure in defining a circuit on the wafer. Chemical vapor deposition (CVD) processes are widely used to form layers of materials on a semiconductor wafer. Other

67,200-1224  
2003-0217

processing steps in the fabrication of the circuits include formation of a photoresist or other mask such as titanium oxide or silicon oxide, in the form of the desired metal interconnection pattern, using standard lithographic techniques; subjecting the wafer substrate to a dry etching process to remove the conducting layer from the areas not covered by the mask, thereby leaving the metal layer in the form of the masked pattern; removing the mask layer using reactive plasma and chlorine gas, thereby exposing the top surface of the metal interconnect layer; cooling and drying the wafer substrate by applying water and nitrogen gas to the wafer substrate; and removing or stripping polymer residues from the wafer substrate.

[003] CVD processes include thermal deposition processes, in which a gas is reacted with the heated surface of a semiconductor wafer substrate, as well as plasma-enhanced CVD processes, in which a gas is subjected to electromagnetic energy in order to transform the gas into a more reactive plasma. Forming a plasma can lower the temperature required to deposit a layer on the wafer substrate, to increase the rate of layer deposition, or both. However, in plasma process chambers used to carry out these various CVD processes, materials such as polymers are coated onto the chamber walls and other interior chamber components and surfaces during the processes. These polymer

67,200-1224  
2003-0217

coatings frequently generate particles which inadvertently become dislodged from the surfaces and contaminate the wafers.

[004] The chemical vapor deposition, etching and other processes used in the formation of integrated circuits on the wafer substrate are carried out in multiple process chambers. The process chambers are typically arranged in the form of an integrated cluster tool, in which multiple process chambers are disposed around a central transfer chamber equipped with a wafer transport system for transporting the wafers among the multiple process chambers. By eliminating the need to transport the wafers large distances from one chamber to another, cluster tools facilitate integration of the multiple process steps and improve wafer manufacturing throughput.

[005] A typical conventional integrated cluster tool is generally indicated by reference numeral 10 in Figure 1. An integrated cluster tool 10 such as a Centura HP 5200 tool sold by the Applied Materials Corp. of Santa Clara, Ca., includes one or a pair of adjacent load-lock chambers 12, each of which receives a wafer cassette or holder 13 holding multiple semiconductor wafers 28. The load-lock chambers 12 are flanked by an orientation chamber 14 and a cooldown chamber 16. Multiple process chambers 18 for carrying out various processes in the fabrication of

67,200-1224  
2003-0217

integrated circuits on the wafers 28 are positioned with the orientation chamber 14, the cooldown chamber 16 and the load-lock chambers 12 around a central transfer chamber 20. A transfer robot 22 in the transfer chamber 20 is fitted with a transfer blade 24 which receives and supports the individual wafers 28 from the wafer cassette or holder 13 in the load-lock chamber 12. The transfer robot 22 is capable of rotating the transfer blade 24 in the clockwise or counterclockwise direction in the transfer chamber 20, and the transfer blade 24 can extend or retract to facilitate placement and removal of the wafers 28 in and from the load lock chambers 12, the orientation chamber 14, the cooldown chamber 16 and the process chambers 18.

[006] In operation, the transfer blade 24 initially removes a wafer 28 from the wafer cassette 13 and then inserts the wafer 28 in the orientation chamber 14. The transfer robot 22 then transfers the wafer 28 from the orientation chamber 14 to one or more of the process chambers 18, where the wafer 28 is subjected to a chemical vapor deposition or other process. From the process chamber 18, the transfer robot 22 transfers the wafer 28 to the cooldown chamber 16, and ultimately, back to the wafer cassette or holder 13 in the load-lock chamber 12.

67,200-1224  
2003-0217

[007] As shown in Figure 2, each load-lock chamber 12 includes a chamber wall 30 defining a chamber interior 32. A cassette stage 34 is mounted on the upper end of a lift shaft 36 which adjusts the height of the cassette stage 34 in the chamber interior 32. The lift shaft 36 extends through a shaft opening 38 provided in the bottom of the load-lock chamber 12.

[008] During operation of the integrated cluster tool 10, a wafer cassette 13 is supported on the cassette stage 34. The lift shaft 36 raises and lowers the cassette stage 34 and wafer cassette 13 in the chamber interior 32, to align wafers 28 (Figure 1) with a slot (not shown) provided in the chamber wall 30. The transfer blade 24 of the transfer robot 22 extends through the slot to transfer the wafers 28 from and load the wafers 28 onto the wafer cassette 13.

[009] One of the problems which is inherent in operation of the conventional load-lock chamber 12 is that gases 40 tend to flow into the chamber interior 32, through the shaft opening 38 and between the lift shaft 36 and the chamber wall 30. These gases react with material layers (not shown) deposited on the surfaces of the substrates 28 contained in the cassette 13. Accordingly, a novel load-lock chamber is needed which prevents the flow of

67,200-1224  
2003-0217

gases into a load-lock chamber, between the lift shaft and the chamber wall, during operation of the load-lock chamber.

[0010] An object of the present invention is to provide a novel load-lock chamber having a gas-sealing bellows to prevent gases from entering the bottom of the chamber and reacting with material layers on a substrate.

[0011] Another object of the present invention is to provide a novel load-lock chamber having a gas-sealing bellows and a rotating mechanism for rotating or indexing a cassette stage in the chamber.

[0012] Still another object of the present invention is to provide a novel load-lock chamber which includes a gas-sealing bellows and a magnetic shaft rotation device for rotating or indexing a cassette stage in the chamber.

[0013] Yet another object of the present invention is to provide a novel load-lock chamber which may include an elongated bellows cavity for containing a gas-sealing bellows; a gas-sealing bellows provided in the bellows cavity for sealing a shaft opening in the bottom of the load-lock chamber; a shaft extending through the shaft opening; a wafer cassette stage provided on the

67,200-1224  
2003-0217

shaft; and a magnetic rotation device for rotating a shaft and the wafer cassette stage.

#### Summary of the Invention

[0014] In accordance with these and other objects and advantages, the present invention is generally directed to a novel load-lock chamber having a gas-sealing bellows to prevent the flow of gases from outside the chamber interior, into the chamber through a shaft opening in the bottom of the chamber. A lift shaft extends through the shaft opening. A cassette stage is provided on the upper end of the lift shaft, inside the chamber interior. The invention includes a load-lock chamber having a chamber wall. A bellows housing having an interior bellows cavity extends downwardly from the bottom of the load-lock chamber. A flexible bellows contained in the bellows cavity surrounds the lift shaft and seals the shaft opening between the lift shaft and the interior of the load-lock chamber. A shaft rotation device, which may be magnetic, surrounds the lift shaft to rotate and index the cassette stage with respect to a wafer slot provided in the chamber wall of the load-lock chamber.

#### Brief Description of the Drawings

[0015] The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

67,200-1224  
2003-0217

[0016] Figure 1 is a top view of a typical conventional cluster tool used in the processing of semiconductor wafers;

[0017] Figure 2 is a schematic of a load-lock chamber of the cluster tool shown in Figure 1;

[0018] Figure 3 is a schematic of a load-lock chamber with gas-sealing bellows of the present invention; and

[0019] Figure 4 is a side view of a bellows and a shaft rotation device surrounding a lift shaft of the load-lock chamber shown in Figure 3.

#### Detailed Description of the Invention

[0020] The present invention has particularly beneficial utility in preventing the flow of gases from outside a load-lock chamber into the chamber interior through a shaft opening in the bottom of the chamber. However, the present invention is not so limited in application, and while references may be made to such load-lock chamber, the present invention is more generally applicable to sealing a shaft opening in process chambers used in a variety of industrial and mechanical applications.



[0021] The present invention contemplates a novel load-lock chamber which is provided with a gas-sealing bellows that blocks the flow of gases from outside the chamber, into the chamber interior through a shaft opening in the bottom of the chamber. Consequently, gases are incapable of flowing from outside the chamber, into the chamber interior through the shaft opening. The gases are thus incapable of reacting with material layers deposited on the surfaces of semiconductor wafers contained in a wafer cassette or holder inside the chamber interior.

[0022] The invention typically includes a bellows housing which extends downwardly from the load-lock chamber and defines a bellows cavity. The bellows is contained in the bellows cavity. The invention typically further includes a shaft rotation device which rotates or indexes a cassette stage provided on the upper end of a lift shaft that extends through the shaft opening in the bottom of the load-lock chamber. The shaft rotation device may be magnetic.

[0023] Referring to Figure 3, an illustrative embodiment of the load-lock chamber of the present invention is generally indicated by reference numeral 42. The load-lock chamber 42 may be a part of an integrated cluster tool in which semiconductor wafers are sequentially transferred among multiple processing chambers, such

67,200-1224  
2003-0217

as chemical vapor deposition chambers, physical vapor deposition chambers and etching chambers, for example. Typically, such an integrated cluster tool includes a pair of adjacent load-lock chambers, one of which is used to load pre-processed wafers into the tool and the other to unload the processed wafers from the tool. However, it is understood that the load-lock chamber 42 may be included as a part of other systems used in the processing of semiconductor wafers.

[0024] As shown in Figure 3, the load-lock chamber 42 includes a chamber wall 44 that defines a chamber interior 46. The chamber interior 46 is adapted to contain a wafer cassette or holder 74, which may be conventional and contains multiple semiconductor wafers (not shown). A chamber door 45 is provided in the chamber wall 44 to facilitate opening and closing of the chamber interior 46. An elongated wafer slot 72 is typically provided in the chamber wall 44 to facilitate the removal of wafers (not shown) from, and/or insertion of wafers into, the cassette 74 in the chamber interior 46, as hereinafter described.

[0025] An elongated bellows housing 48 extends downwardly from the chamber wall 44 and defines an interior bellows cavity 50. A housing bottom 49 partially closes the bottom of the bellows cavity 50. A shaft opening 52 extends through the housing bottom

67,200-1224  
2003-0217

49 of the bellows housing 48. An elongated lift shaft 62, the bottom end of which is engaged by a shaft elevation motor 78, extends through the shaft opening 52. A cassette stage 64 is provided on the upper end of the lift shaft 62, inside the chamber interior 46, to support the cassette 74.

[0026] An elongated, flexible bellows 54, having multiple folds 54a, is contained in the bellows cavity 50. Preferably, the bellows 54 is a metal alloy. Most preferably, the bellows 54 is AM350 stainless steel. However, it is understood that the bellows 54 may be constructed of any alternative suitable material which is corrosion-resistant.

[0027] The bottom end of the bellows 54 is attached to the housing bottom 49 in a fluid-tight seal, according to the knowledge of those skilled in the art. In similar fashion, the upper end of the bellows 54 is attached in a fluid-tight seal to a bellows mount frame 56, which may be cylindrical. Accordingly, a bellows interior 55 of the bellows 54 is disposed in communication with the shaft opening 52, whereas a fluid-tight seal is provided between the bellows interior 55 and the chamber interior 46.

[0028] Referring to Figure 4, the bellows mount frame 56 includes a circumferentially-extending flange 56a to which is mounted a shaft mount plate 58. A plate mount collar 60 is welded, bolted or otherwise attached to the shaft mount plate 58. The plate mount collar 60 further mounted on the lift shaft 62, yet permits rotation of the lift shaft 62 with respect to the plate mount collar 60. The plate mount collar 60 may be mounted on the lift shaft 62 by means of an annular flange (not shown) which extends from the plate mount collar 60 and inserts in a circumferential groove (not shown) provided in the exterior surface of the lift shaft 62, for example.

[0029] A shaft rotation device 66, which may be conventional, is mounted on the shaft mount plate 58. An example of a shaft rotation device 66 which is suitable for the present invention is the magnetic shaft rotation device available from Trade Mark Electronics (TME), Inc. The shaft rotation device 66 typically includes a housing 68 which contains a toroidal or annular housing magnet 70 that is provided around the inner surface of the housing 68.

[0030] The lift shaft 62 extends through the bellows interior 55 of the bellows 54, into the housing 68, and is surrounded by the housing magnet 70, which magnetically rotates the lift shaft 62

in the housing 68, as hereinafter further described. A power supply and controller 76 (Figure 3) is operably connected to the shaft rotation device 66 to control the polarity of the housing magnet 70 and selectively rotate the lift shaft 62 among multiple positions in the housing 68.

[0031] As further shown in Figure 4, a mount plate 61 may be provided between the upper end of the housing 68 and the shaft mount plate 58 to mount the housing 68 of the shaft rotation device 66 to the shaft mount plate 58. A shaft bearing 69 is typically provided on the bottom end of the housing 68. Accordingly, the lift shaft 62 extends through the shaft bearing 69, the housing magnet 70 in the housing 68, the mount plate 61, the shaft mount plate 58 and the plate mount collar 60, respectively.

[0032] The shaft bearing 69 centralizes the lift shaft 62 in the housing 68 while permitting smooth rotation of the lift shaft 62. Furthermore, the plate mount collar 60 mounts the shaft mount plate 58 and bellow mount frame 56 to the lift shaft 62, such that the bellow mount frame 56 is raised and lowered in the chamber interior 46 as the lift shaft 62 is raised and lowered by actuation of the shaft elevation motor 78. Simultaneously, the plate mount collar 60, mount plate 61 and shaft bearing 69 permit

67,200-1224  
2003-0217

free rotation of the lift shaft 62 with respect to those elements.

[0033] Referring again to Figure 3, in operation of the load-lock chamber 42, the chamber door 45 on the load-lock chamber 42 is initially opened to provide access to the chamber interior 46. Next, a cassette 74, which contains multiple semiconductor wafers (not shown) to be processed in a multi-chamber integrated cluster tool (not shown), for example, is placed on the cassette stage 64, inside the chamber interior 46. The chamber door 45 is then closed and sealed, and the chamber interior 46 is purged with nitrogen or other inert purging gas. Desired chamber pressures may be established in the chamber interior 46, as well.

[0034] By actuation of the shaft elevation motor 78, the lift shaft 62 is then raised in the chamber interior 46 to raise the cassette 74 to the level of the wafer slot 72 in the chamber wall 44. Simultaneously, the resilient bevel 54 stretches from the compressed configuration shown in Figure 4 to the expanded configuration of Figure 3, while maintaining a fluid-tight seal between the shaft opening 52 and the chamber interior 46. Accordingly, gases flowing into the shaft opening 52 from the exterior of the load-lock chamber 42 accumulate in the bellows

67,200-1224  
2003-0217

interior 55 and are thus prevented from entering the chamber interior 46.

[0035] Once the cassette 74 has been raised to the level of the wafer slot 72, the cassette 74 can be rotationally positioned or indexed, as necessary to align the cassette 74 with the wafer slot 72. This facilitates the subsequent unloading of wafers from the cassette 74, through the wafer slot 72, and into a processing chamber (not shown) in the integrated cluster tool, for example, typically by operation of a wafer transfer robot (not shown), as is known by those skilled in the art.

[0036] Rotational positioning of the cassette 74 in the chamber interior 46 is carried out by actuation of the controller 76, wherein the housing magnet 70 in the housing 68 of the shaft rotation device 66 magnetically rotates the lift shaft 62, and the cassette stage 64 mounted thereon, in the selected clockwise or counterclockwise direction. When the cassette 74 is sufficiently aligned with the wafer slot 72, rotation of the lift shaft 62 is discontinued and transfer of the wafers from the cassette 74, through the wafer slot 72 and into a processing chamber (not shown) is begun.

67,200-1224  
2003-0217

[0037] After the wafers have been sequentially unloaded from the cassette 74, the emptied cassette 74 is removed from the chamber interior 46. This is carried out typically by lowering the cassette stage 64, opening the chamber door 45, removing the cassette 74 through the door opening, and closing the chamber door 45. Upon lowering of the lift shaft 62, the bellows 54 partially compresses, thereby expelling gases from the bellows interior 55 and from the bellows housing 48 through the shaft opening 52.

[0038] While the preferred embodiments of the invention have been described above, it will be recognized and understood that various modifications can be made in the invention and the appended claims are intended to cover all such modifications which may fall within the spirit and scope of the invention.